THE INSTITUTE OF PHYSICS
47 BELGRAVE SQUARE, LONDON, S.W.1.

# BULLETIN

VOLUME 6
1955

THE INSTITUTE OF PHYSICS
47 BELGRAVE SQUARE, LONDON, S.W.1.

# BULLETIN

VOL. VI, No. 1 JANUARY, 1955

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## APPOINTMENTS VACANT

**The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.**

**Physicist. Tootal Ltd.,** have a vacancy for a man with honours degree or Ph.D., aged under 30, in one of their manufacturing units. The post provides an excellent opportunity for the application of the scientist's trained habit of enquiry to technical problems of efficiency on the shop floor. The work is interesting and important, will be paid accordingly, and offers good prospects. Neither previous experience of textiles, nor of industry generally is necessary. Applications giving details of age, education, qualifications and experience should be addressed to the Personnel Manager, Tootal Broadhurst Lee Co. Ltd., 56 Oxford Street, Manchester 1.

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**Research Laboratories, British Electricity Authority, Leatherhead,** require two general **assistant engineers.**

Candidates should have a university degree or equivalent qualifications in electrical engineering or in physics. Duties include research on electrostatic precipitation and allied problems at Leatherhead and Croydon laboratories.

Salary N.J.B. Grade 4, £675–£850 p.a.

Applications stating age, qualifications, experience and present position and salary should be forwarded to D. Moffat, Director of Establishments, Winsley Street, London, W.1, by January 17, 1955. Quote reference BIP/541.

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**The British Paper and Board Industry Research Association** has a vacancy for a young **physicist** with an honours degree. He should have an interest in classical physics, fluid mechanics and statistical analysis. He would be required to work with a small team engaged on a long-term study of the principles of operation of papermaking machines, and, in particular, or fluid flow of pulp suspensions. The starting salary will be £550 – £575 and £605 will be paid after a successful probation period of six months. A higher salary will be paid to older and more experienced graduates. The post is permanent and pensionable under F.S.S.U. and there are good prospects of promotion in the laboratory and in the paper-making industry. Applications, giving full details of career, should be addressed to the Director, The British Paper and Board Industry Research Association, St. Winifred's Laboratories, Welcomes Road, Kenley, Surrey.

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**Electrical Research Association. Technical Assistant** required for research on applications of electricity in food industries. Qualifications expected are a good degree in electrical engineering or physics with some knowledge of electronics. Research experience an advantage. Starting salary will be in the range of £500 – £600 p.a. with superannuation provisions. Applications should be addressed to the Director, E.R.A. Field Station, Shinfield Green, Nr. Reading, to arrive not later than January 10, 1955.

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**Kodak Ltd.** have a vacancy for an honours **physics graduate** in their research laboratories for research and development work in connection with the production of photographic material and apparatus. Candidates should be under 30 years of age. Apply by letter to Personnel Department (Factories), Headstone Drive, Wealdstone, Middlesex.

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**University of Sydney.** Applications are invited for five **research studentships/fellowships** in the **school of physics.**

The successful applicants will be appointed, according to qualifications and experience, to a research studentship (£A750–£A850 per annum), to a junior research fellowship (£A900 per annum) or to a senior research fellowship (£A950–£A1,300 per annum).

Fares to and from Australia, not exceeding a total of £A200 may be paid.

The awards will normally be made for a period of two years, after which the tenure may be renewed for a further period.

Pre-doctoral candidates will normally be awarded research studentships and will be expected to pass the physics IV examination at honours B.Sc. level before proceeding to work for the Ph.D. degree. Study for this examination may take up part or all of the first year in Sydney. Experimental work in the school of physics is directed by Dr. E. P. George and nuclear research emulsions, cloud chambers and counters are used in experiments covering many aspects of cosmic ray research. Theoretical research is under the direction of Professor H. Messel and investigations into problems of nuclear, atomic and solid-state physics are in progress. A large high-speed digital computer is under construction.

Applications, giving full details of qualifications and experience and the names of referees, should be forwarded to reach the Registrar, University of Sydney, Sydney, Australia, by 28th February, 1955. In addition, a copy of the application should be forwarded to the Secretary of the Association of Universities of the British Commonwealth, 5 Gordon Square, London W.C.1, by the same date.

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**Physicist or Chemical Engineer,** graduate or equivalent training, required for research and development on vacuum drying and allied problems. Must have laboratory experience, preferably in the vacuum and/or refrigerating fields. Permanent pensionable position with commencing salary according to age and experience and commensurate with the first-class man sought. Housing available. Applications with full details to Personnel Officer, W. Edwards & Co. (London) Limited, Manor Royal, Crawley, Sussex.

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**Vacuum Physicist—Qualified physicist or equivalent,** required for research and development of instruments and apparatus including electron, optical, mechanical and ionization devices. Previous high vacuum experience a distinct advantage. Permanent pensionable position. Housing available. Commencing salary according to age and experience and commensurate with first-class man sought. Detailed applications to Personnel Officer, W. Edwards & Co. (London), Limited, Manor Royal, Crawley, Sussex.

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**Nelson Research Laboratories, Stafford,** have a vacancy for an experimental graduate **physicist** for interesting work on semi-conducting materials. Experience in this field is desirable but not essential. Reply stating age, qualifications and experience to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. 312.

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THE INSTITUTE OF PHYSICS

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## PAYMENT OF ANNUAL FEES

As was announced in the December *Bulletin*, members who do not pay their fees by Bankers Order are asked to co-operate in reducing the cost and labour of collecting fees by using the form printed opposite. Details of the various amounts which should be included in remittances to cover annual membership subscriptions and the costs of journals are given below.

### Membership Subscriptions

Annual subscriptions are payable according to the following scale :—

| | Resident in United Kingdom | | | Resident Overseas | | |
|---|---|---|---|---|---|---|
| | £ | s. | d. | £ | s. | d. |
| Fellow ... ... ... ... ... | 5 | 5 | 0 | 3 | 3 | 0 |
| Fellow who compounded as an Associate | | | | | | |
| (i) before July 22, 1943 ... ... | 4 | 4 | 0 | 2 | 2 | 0 |
| (ii) after July 22, 1943 ... ... | 3 | 3 | 0 | 1 | 1 | 0 |
| Associate ... ... ... ... ... | 3 | 3 | 0 | 2 | 2 | 0 |
| Graduate ... ... ... ... | 2 | 2 | 0 | 1 | 1 | 0 |
| Subscriber ... ... ... ... | 2 | 2 | 0 | 1 | 1 | 0 |
| Student ... ... ... (*see page* 19) | | 10 | 6 | | 5 | 0 |

Subscribers under the age of 21 who are *in statu pupillari* are required to pay only the Student fee but they are then ineligible to claim privileged rates of subscription to the Institute's journals.

Graduates serving their term of National Service are required to pay a subscription of only 10s. 6d. annually.

Students serving their term of National Service are required to pay only one subscription of 10s. 6d. for the period of their two years' service.

### Institute's Journals

The annual retail subscription for the *Journal of Scientific Instruments* and the *British Journal of Applied Physics* is £4 0s. 0d. for each journal, but members of all grades of the Institute are entitled to the following concessions :—

*Fellows and Associates* are entitled to one journal without additional payment above their membership fees, and to the other at the reduced

rate of £1 1s. 0d. per annum. Journals taken by Fellows and Associates are automatically renewed each year unless fresh instructions are given.

*Graduates and Students* may subscribe to either or both of the Institute's journals at £1 1s. 0d. each per annum. Subscriptions cease at the end of each year and no journals are despatched until a new order and payment have been received. (Those paying by Bankers Order will, however, continue to receive any journals already ordered).

*Subscribers* may have either of the Institute's journals at £1 11s. 6d. per annum and may also subscribe to the second journal at £2 2s. 0d. per annum. Subscriptions cease at the end of each year and no copies are despatched until the order and payment has been received.

**Publications of other bodies available to members at reduced rates for their personal use only**

| | Reduced rate per annum |
|---|---|
| The Institution of Electrical Engineers | |
| *Science Abstracts* | £ s. d. |
| Physics Abstracts ... ... ... ... ... | 2 0 0 |
| Physics Abstracts (single sided) ... ... ... | 2 10 0 |
| Electrical Engineering Abstracts ... ... ... | 2 0 0 |
| Electrical Engineering Abstracts (single sided) ... | 2 10 0 |
| Both sections together ... ... ... ... | 3 12 6 |
| Both sections together (single sided) ... ... | 4 12 6 |
| *Journal* ... ... ... ... ... ... | 12 6 |
| *Proceedings*—Part A ... ... ... ... ... | 17 6 |
| *Proceedings*—Part B ... ... ... ... ... | 17 6 |
| *Proceedings*—Part C ... ... ... ... ... | 7 6 |
| All three parts together with the journal ... | 2 10 0 |
| The Physical Society | |
| *Proceedings*, Part A OR *Proceedings*, Part B (only one part may be taken) | 2 12 6 |

**Benevolent Fund**

Members wishing to make donations to the Benevolent Fund should include these in their remittances and enter the amount in the appropriate space on the form.

## GALILEO GALILEI*

By F. SHERWOOD TAYLOR, M.A., Ph.D.
(*Director, Science Museum, London*)

Galileo Galilei is known to the world as the man who was condemned by the Inquisition for his astronomical opinions, and many who know this know little else about him. My present purpose is to try to show you what Galileo was trying to do and why it was important, and only secondarily to consider how he came in conflict with the Church.

First let me try to show you Galileo Galilei against his social and cultural background. He was born in the same year as Shakespeare (1564) but lived longer, dying in 1643, the year in which Newton was born. He lived in Italy, not long after its period of highest culture, in a polished, wealthy and highly intelligent society. He himself was a man of culture and versatility, an excellent painter and musician as well as being a brilliant and forceful writer of his own tongue. He had every advantage except money, and once he came under the patronage of the Duke of Tuscany, that was not lacking either. He was a happy, sanguine, clubbable man who enjoyed life to the full as long as there was anything to enjoy, who expected to be liked and was very surprised when he found that his sharp pen had made him enemies.

*Fig. 1. Galileo, aged Forty.*

Galileo was one of the first whom we may call a whole-time scientist—one who devotes his whole time to the pursuit of science. Unlike the majority of the scientists of earlier ages he was not a cleric, nor did he hold any office or carry on any business. In the latter part of his life he did not even teach, but devoted himself to his scientific researches and writings.

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*A lecture given before the Institute's Education Group on November 10, 1954. Part of this lecture is based upon a lecture given at the Royal Institution and will appear in *An Illustrated History of Science* to be published by Messrs. Wm. Heinemann early in 1955.

What of the scientific background ? First we may say that the science of the Greeks, somewhat augmented but not altered in principle, still held sway in the sixteenth century. The universe was still a sphere with the earth at its centre : the heavens and the bodies therein were of a mysterious subtle " fifth element," while the earth and all below the sphere of the moon was composed of the four elements of earth, water, air and fire. In the heavens there was no change but motion : in the earthly region alone was there coming-to-be and passing away. The whole system stood or fell together—that is to say it was logically derived from principles adopted by Aristotle and if these proved false so did the whole scheme : moreover it was interwoven with religion—not inextricably, but in such a way that its abandonment would mean much readjustment of cherished and feeling-laden ideas.

This ancient world-view had not gone unquestioned. Thus Copernicus in 1543 had published a heliocentric astronomy, and many speculators had cast doubt on the existence of the four elements—or of some of them. But before Galileo's time these attacks were not taken seriously except by a few astronomers and philosophers. Galileo's life's work was to attack this whole scheme, show the Greek assumptions and conclusions to be false and begin a new science grounded on direct observation.

For this task he was very well equipped in that he had a taste for mechanic's work and took pleasure in making for himself the apparatus, most of which in those days it was impossible to buy. Unfortunately he left no systematic records of his experimental work : we have to read between the lines to reconstruct the picture of his workshop and laboratory. But even more important than his physical skill was his freedom from the prejudices of the past. He had a certain instinct for rejecting the pseudo-sciences. Alchemy did not interest him : astrology he regarded as nonsense, refusing to draw horoscopes even for his friends : he even rejected as untrue the influence of the moon on the tides, which seemed to him to be an occult notion. In all this he was in the strongest contrast to most of the men of his time.

What then was the basis of the Greek view of the world ? First, we may say, the simple and natural inferences that spring from unaided and unanalysed perception. The earth seems to be *the* motionless body, on which man and other bodies move : the stars and planets seem to move around it and they seem to move in circles. Again men have always thought of the complex as derived from the simple : hence the notion of *elements* as constituents of things. Again man regards himself dualistically, as of body and spirit : so the early natural philosophers tended to seek that sort of division in considering

any phenomenon susceptible to it. This attitude to the world the Greeks doubtless inherited, perhaps from the Mesopotamian civilizations. They then proceeded to rationalize it, to bring evidence and arguments that it was so. The work of many Greek thinkers was summed up and critically examined in the works of that very great philosopher and teacher, Aristotle, who tried to reconcile all these theories and make a sort of encyclopaedia of the best-accepted knowledge of his time. His writings were largely preserved, while those of most of the other Greek scientists perished ; so it was his ideas that were passed on to the men of later times and came to be accepted, almost as articles of faith. So let us see what Aristotle thought about what things are made of and how they move.

First of all he supposed that all the properties of things could be summed up by saying they were hot or cold and moist or dry in varying degrees. These varying degrees he explained by supposing four elements, having the four possible permutations of those qualities. Fire was hot and dry, Air was hot and moist, Water was cold and moist, Earth was cold and dry. Everything on earth was made of combinations of these elements, and all major changes (other than motion) depended on alterations of the proportions of these elements. Certainly he and his followers could explain a great many changes in that way : but the trouble was that there was not much visible evidence for the very existence of his earth, air, fire and water in things.

But what about the sun, moon and stars ? Were they made of any of these elements ? By no means : the four earthly elements changed one into another, but the sun, moon and stars were imperishable. They moved but they did not seem to come to be or pass away. They must therefore be of some other element, more subtle and spiritual than those of earth.

Now Aristotle, having satisfied himself that these five elements, earth, water, air, fire, and the fifth element, were the basis of things, went on to ask " *Why* and *how* do things move, both in the heavens above and on the earth below ? " And he gave as a reason that *each element goes naturally to its proper place*, unless it is forced to go somewhere else. Fire went naturally up—away from the centre of the earth (for the Greeks and everyone after them knew the earth was a sphere)—till it reached the surface of the sphere of the moon where the celestial world began. Earth sank down as near the centre as it could get. Water sank below air but stayed above earth. Air rose above water but stayed below Fire. In the mediaeval diagram of the Universe we can see (starting from the centre), Earth, Water, Air, Fire, and the heavenly regions, all in their proper places.

In the heavens the fifth element had a natural circular motion. Clearly the stars moved in circles and so Aristotle adopted the idea

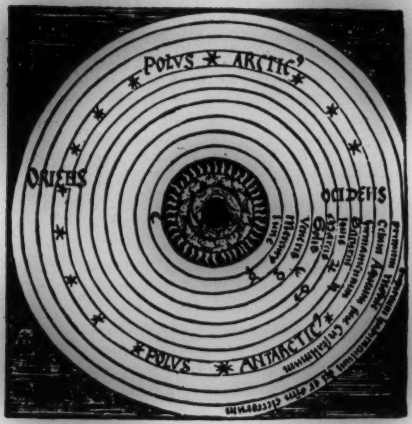


*Fig. 2. The Universe according to the system of Aristotle.*

that everything in the sky went round in circles because so to do was of the nature of the element they were made of. The circle was the perfect figure and everyone was so convinced of this that even after 1609 it was hard for Kepler to persuade himself that a planet could move in an ellipse.

Then Aristotle asked himself what laws expressed the motion of ordinary heavy bodies, here on earth : and he came to wrong conclusions that led science on a false trail for some eighteen centuries. I suppose that he watched heavy bodies like stones and light bodies like leaves falling through air or sinking through water. He came to the natural conclusion that the heavier a body was the faster it fell, and the thicker the stuff it fell through, the slower it fell. A stone fell quicker than a leaf and it sank more slowly through honey than through water. In a general sort of way he was right, but if you are going to found a science on observations they ought to be exact ones. Aristotle did not make any measurements nor did he consider the acceleration of falling bodies, and he concluded :—

(1) that the speed of a falling body is proportional to its weight, i.e. a 10 lb. stone falls ten times as fast as a 1 lb. stone ;

(2) that the speed of fall is inversely proportional to the resistance of the medium the body falls through.

This simply was not true ; but worse was to come. We have seen that he believed that the speed of fall of a body was inversely proportioned to the resistance of the medium it fell through. A vacuum would have no resistance : therefore a body would fall at infinite speed through it. Which, Aristotle said, was absurd, so it is impossible that a vacuum can exist.

But if there cannot be a vacuum, there cannot be atoms, for these must move and so, if they existed, there would have to be vacuum between them. What a tangle resulted from these clever arguments from untrue facts !

Such were Aristotle's notions about the " natural " motion of bodies : but what of his idea of their " violent " motion ? Aristotle supposed that when someone shot an arrow or threw a stone something kept it in motion : indeed he supposed that the air which was pushed away from the front came round and pushed the arrow from the back ! The crucial experiment would have been to try to project a body in a vacuum, for according to Aristotle it was impossible to *throw* a stone horizontally in a vacuum, though it would *fall* with infinite velocity. But this experiment could not be done, for no-one in the world yet knew how to make a vacuum.

So the Aristotelean ideas of motion were not merely interesting observations and theories, true or false, but on them hung many conclusions, e.g. that the universe was spherical, a vacuum impossible, and atoms impossible, each of which was in their turn the source of innumerable deductions.

It was therefore of the greatest importance to decide whether Aristotle's assumptions were correct. Did bodies fall at a rate proportional to their weight ? As far as we know nobody tried the experiment between c.330 B.C. and 1580 A.D. Then Simon Stevin dropped two weights, one ten times heavier than the other, from 30 feet height on to a board and announced that they fell so nearly together as to make only one bang when they hit it. Galileo probably did not know of this. But he seems to have done much the same kind of experiment though he does not tell us when or where. He certainly more than once dropped two different weights from high places and noticed that the two weights reached the ground nearly but not *exactly* together, if the height was great ; he thus observed that the velocities of a 10 lb. and 1 lb. weight freely falling through air were certainly not ten to one (as Aristoteleans supposed) but more like ten to nine. But he went much further than Stevin, who only *disproved* Aristotle's views, in that he set to work to find out how falling bodies really did move. Aristotle had said nothing about acceleration ; but one or two learned mediaevel philosophers had argued that the " heaviness " of a falling

body body continues to act throughout its fall, and, consequently, a falling body ought to be accelerated. They even worked out the right law, but they did not test it in order to see for themselves whether they were right or not !

Galileo tried to *observe* the acceleration of falling bodies. But how was he to do it ? There were no stopwatches or chronographs, but only very crude and inaccurate blacksmith's clocks without minute hands, as a rule, let alone second hands. So instead of trying to time anything moving as fast as a metal ball dropping from a tower, he timed metal balls rolling down slopes. He saw that, if the slope was increased till it was vertical, the rolling became identical with falling, and so the same law ought to apply to rolling and falling. To this end he designed a piece of apparatus—a novel thing to do in those times.

He made a beam 22 feet long, set edgeways so as not to bend and having a groove in which a brass ball could roll. How was he to time it ? For this he went back to the old Egyptian water-clock—a bucket with a hole in it ; he weighed the water that flowed while the ball was running and he found the ball took *half* the time to run a *quarter* of the distance : and by a series of experiments he showed that the distance run by the ball was as the square of the time needed to run it. In other words distance/square of time was constant for a given slope. This result could be deduced from the theory that while the ball ran down the slope it was uniformly accelerated.

Thus Aristotle's views about the velocity of " natural motion " of bodies were confuted. What of his views of violent motion ?

Throughout the middle ages many philosohpers had disagreed with Aristotle and had thought that the moving arrow, or what you will, had a *quality* that kept it going, which they called " impetus " : Galileo was of the same opinion, though he said nothing of qualities and simply expressed his opinion that if nothing stopped a moving body it would go on for ever. He asked us to imagine a smooth plane sloping never so little downward. On that a moving ball would accelerate. If it sloped never so little upwards the ball would decelerate. So if it were level and smooth and the sources of friction were imagined away, he said, the ball would go on for ever. This experiment could not be done, of course : we may call it a " thought-experiment."

Now these two ideas, first that a body proceeding downward was accelerated, secondly that a body proceeding horizontally kept a constant speed, enabled Galileo to solve a problem that had long been puzzled, namely to specify the curve followed by a projectile. Some thought a cannon ball went straight out of the cannon, then began to curve, then dropped sheer : others such as Leonardo came very close to the true curve, but no one had specified it mathematically. But Galileo

saw that in each second the projectile travelled the same distance horizontally (like the imaginary ball on the plane) but at the same time it fell through distances, which were as the square of the time of fall, 1, 4. 9, 16, 25, etc. The curve which fulfilled these conditions had been known since the time of the Greeks and was a parabola.

Galileo much desired to investigate air and try to make a vacuum. Aristotle considered that air had no weight and Galileo set out to prove the contrary. He could not do as we do, weigh a flask first evacuated, then full of air, because there were not air-pumps. So he thought of a very pretty plan. He fitted a bottle with a leather valve and tube. He forced water into it so as to compress the air ; he then weighed the bottle ; next released the pressure by pushing down the valve and then weighed it again. How much air was released from the bottle ? Clearly a volume equal to that of the water forced into it. So the loss of weight that took place when the pressure was released was the weight of that much air ! Galileo made the weight of the air about twice what it should be : he probably lost a drop of water through the valve. Galileo tried hard to make a vacuum and he quite possibly did so by filling a cylinder with water and pulling out the piston. But it was not quite convincing. The feat was accomplished by one of his friends and pupils after his death, namely Torricelli. Such a simple experiment really, yet it proved the possibility of the vacuum and demonstrated the huge pressure of the atmosphere which nobody had realized.

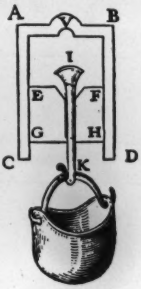


*Fig. 3.*
*The apparatus in which Galileo claimed to have produced a vacuum.*

The announcement of these experiments in fact destroyed the Aristotelian system as far as it concerned terrestrial things. Men took some time to realize what had happened, but within 25 years of Galileo's death it was not maintained by any serious natural philosopher, and Huygens and Newton were already building up a scientific dynamics.

The other great sub-division of Galileo's work was his astronomy, likewise directed to the destruction of the ancient cosmology. From his early years he seems to have been a believer in the ideas of Copernicus : moreover he thought that the evidence of the novae of 1572 and 1604 showed that the heavenly bodies were not ingenerable and imperishable as Aristotle had supposed. In 1609, by a piece of good fortune he heard that some Dutchmen had made an instrument

with lenses that made far-off things look near. Given this hint it did not take him long to devise a telescope, and as he was a very skilful

*Fig. 4. Galileo aged about forty-five. The cherub is holding a telescope of the trumpet shape often adopted in the earliest period.*

worker with his hands he soon made an instrument that gave good definition, and forthwith he pointed it to the skies !

Galileo was already a good astronomer and at once understood the significance of what he saw through his telescope.

His first great discovery was concerning the moon. According to the Aristotelians, it should have been a perfectly smooth sphere composed of the fifth element. He studied the boundary between light and darkness rather before the period of half moon. Inside the dark part he saw spots and lines of light and he interpreted these spots and

lines as the summits of mountains and the rims of the valleys lighted up by the rising sun. He proclaimed the moon to be a solid rugged body like the earth. That the moon should be another world aroused enormous excitement and interest.

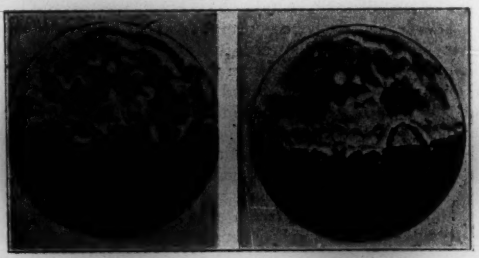

*Fig. 5. The moon as seen by Galileo with his telescope.*

Next four little stars were always seen to accompany the planet Jupiter, but continually to alter their positions relative to him. Galileo proved that these little stars revolved about Jupiter just as Copernicus had said the moon revolved around the earth. Moreover, here were little bodies rotating round a big body ; and Copernicus had supposed that the little planets rotated round the big sun, not the big sun round the little earth. So these observations supported, if they did not prove, the Copernican system, which had formerly rested only on the fact that it gave a simpler and more orderly picture of the universe.

It is probable (but not certain) that Galileo was the first to observe sun-spots. These showed not only " imperfections " in that luminary but also *changes*—contrary to Aristotle's ideas of a heavenly region where nothing came to be or passed away.

Next Galileo showed that the planet Venus showed phases like the moon and so he concluded it must be an opaque body like the moon or the earth, not some sort of spiritual shining being. The argument was : " If these planets, Venus and the moon, resemble the earth, why not agree with Copernicus that the Earth, like them, is a planet and is not the centre of all things ? "

Galileo's advocacy of the Copernican system precipitated the the question as to whether the ancient cosmology was implied to be true by the Catholic faith.

We may look at the history of this controversy in two ways. First we may examine the feelings and principles that lay behind it :

secondly we may consider the personalities and contingent events that determined what actually occurred.

First as to principles. Let us look back to the time of the revival of learning, which brought the Aristotelean and other Greek texts to light once more through the medium of translations from the Arabic.

Then, in the thirteenth century, there was first an attempt to reject the new knowledge, largely because of the Moslem heresies that accompanied it, then a reaction towards it. Such men as St. Albert and St. Thomas Aquinas, extracted from the Greek science an idea of the world which was compatible with and indeed interfused with Christian doctrine. For a few decades it seemed that all human science was a part of a single idea of the world formed upon Christian doctrine. The enthusiasm faded, but substantially throughout the middle ages science and philosophy were handmaids of theology.

The result was to make those who were not too well acquainted with the bases of science to treat it as if it were revealed or at least authenticated by the Church. Thus the astronomical books drew heaven as a sphere outside that of the fixed stars : so long was it thought of in this way that any astronomical hypothesis that made this impossible was frightening—a threat to the religion men knew and loved. Again one of St. Thomas' proofs of the existence of God started with an axiom of Aristotelean dynamics—a threat to that seemed like a threat of atheism. Men dreaded and suspected a science that might force them to rethink their world-picture. Scientists in the middle ages were generally clerics but in the 16th and 17th centuries came a race of laymen, who might not handle the cherished body of natural philosophy with the care it needed. This is the true reason, I believe, why there was so powerful an emotional reaction to the discoveries and writings of Galileo.

It is not difficult to see then that the second-class official type of mind in the Church was instinctively averse to this new philosophy that threatened their world. They naturally sought, then, for grounds for silencing the controversy. The obvious way of doing this was to prove it to be contrary to Catholic doctrine. They put forward the view that the Copernican astronomy was contrary to certain texts which appeared to assert the motion of the sun and stability of the earth, and further claimed that the interpretation of these texts was fixed, because the Fathers were unanimous in adopting such an interpretation. It was not a question of fact against doctrine. What Galileo had seen was an inference from his observations. If this inference conflicted with Catholic doctrine it must be a wrong inference.

Galileo and his party contended that the Scriptures did not intend to make statements about astronomy and that the Fathers had not considered the question of systems of the world in interpreting these texts. We hold this view to-day.

Such were the arguments : the reason why the former were accepted and the latter rejected by the Holy Office was a matter largely of personalities and politics. Galileo had been twice denounced before 1616 and twice no action had been taken. On the third occasion, however, he had rather unwisely circulated a letter concerning the interpretation of the Scriptures, which, though it is accepted to-day as excellent doctrine, was probably thought to be outside the function of a layman. It is nearly always impossible to know what went on in the private deliberations of the Holy Office, but in the end the question of the motion of the earth and stability of the sun was submitted to the three consultors, who gave a judicial opinion on it. If their reasons were submitted, they are no longer extant. The important fact was the the matter was considered in a narrow legalistic way, and not as one of the great theologians of the Church might have considered it. The Copernican system was condemned and Galileo forbidden to hold, teach or defend it. (Even on this there is doubt). In 1632 he clearly disobeyed this ruling and was condemned to be confined to his house for the remaining seven years of his life.

Such are the main points, but the history of the matter is bedevilled by the polemics of professors of physics, Dominicans and Jesuits, backstairs gossip of Archduchesses and possibly the *amour propre* of Pope Urban VIII. If different people had been concerned the Copernican system and Galileo himself might not have been condemned. But the controversy would still have run its course, and its essential principles would have been unchanged. The Copernican system was very soon permitted to be taught, though the condemnation remained, as a dead letter, until the eighteen thirties.

Galileo's work in astronomy was not so completely destructive of the ancient system as was his work in physics ; it is hard indeed to separate the effect of his work from that of Kepler and Newton. But we are perhaps not far from the truth in thinking of Galileo as the man who destroyed the ancient view of the world, terrestrial and celestial. This destruction was a work most necessary to be done if science were to flourish, but we are not to rate Galileo as a destroyer only, for he was a builder, too. I will not here refer to his actual positive discoveries, but would try to show you what he contributed to science as such.

We should not estimate Galileo's importance simply by what he discovered or the truths of which he persuaded the world : of equal importance perhaps was his contribution to scientific method, his practical exemplification of science in action. Galileo's books showed the world for the first time the practice of science. Here was a man who disregarded doctrines that clung around the Greek and mediaeval science ; who when he considered a question, considered nothing but what he himself could observe, here and now ; who

founded his view of the material world simply and solely upon scientific observations. Here was a man who spent his days in the laboratory, whose method of attack upon a problem was to try to devise a piece of apparatus or an experiment to test rival theories.

His mind turned always to measurement or mathematical treatment of a scientific problem. As he said :—

" Philosophy is written in that very great book, which continually lies open before our eyes (I mean the Universe) ; but we cannot understand it, if we do not first learn the language, and comprehend the characters in which it is written. It is written in the mathematical language, and its characters are triangles, circles and other geometrical figures, without the aid of which it is impossible to understand a word of it, without which one wanders vainly through a dark labryinth."

Galileo's many physical discoveries, other than that of the telescope, are all concerned with measurements or numbers and he is the first to present the scientific view of the world in the form of mathematical formulae. This is a very fruitful practice, because all mathematical expressions are exactly and fully intelligible to all who take the trouble to learn mathematics, while the same cannot be said of any other mode of describing things.

We may say then that he propagated modern scientific methods by his example : on the other hand he does not set out anywhere any specification of scientific method, as did his contemporaries, Bacon and Descartes, both of whom failed to exemplify science in words as well as Galileo did in action.

And, of course, Galileo's condemnation by the Inquisition to confinement in his house (mild as it was by the standards of the day) made him a martyr, and it is as true in science as in religion that " the blood of the martyrs is the seed of the Church."

Galileo's mathematical method of considering the objects of science led him to distinguish a world of science from a world of experience. Galileo took the scientific view of the thing to be the real and important part of it : he attempted to separate the thing, as it were, in itself from the thing as we know it, and was the first to make the great distinction between primary and secondary qualities, which has been a crux in metaphysics ever since.

" However, I say that I feel myself necessarily compelled, as soon as I conceive of a piece of matter of a corporeal substance, to conceive of it as determined and shaped as of such and such a figure, as being great or small in relation to other bodies, as being in this or that place, at this or that time, as being in motion or at rest, as touching or not touching another body, as being one or many ; nor can it by any imagination be separated from these conditions : but that it must be

white or red, bitter or sweet, sounding or mute, of pleasant or unpleasant smell—I do not find myself mentally forced to consider it as necessarily accompanied by such conditions : so that if it were not the senses that conveyed it to us, perhaps neither reason nor imagination by itself would have arrived at them. Thence I am led to think, that these tastes, odours, colours, etc., from the point of view of the objects in which they appear to reside, are no more than pure names, and have their only residence in the sensitive body, so that if the animal were removed all such qualities would be removed and annihilated . . ."

In science, as conceived by Galileo, there was only room for the mathematically expressible properties of size, shape, and motion. But consider a peacock's feather. We perceive its size and shape but no less clearly do we perceive its colour, lustre, beauty. Galileo distinguished the qualities of the feather that did not depend on the human senses from those that did. Redness, greenness, lustre, beauty, cannot be thought of existing apart from an eye and a brain, but size, shape and motion could. So the latter he regarded as the real or primary qualities to be studied by science and the former as little more than illusions or at most properties of one little corner of the world—the human brain.

This view has remained substantially the view of science till the present day. The objects of the scientists' " real world " have size, shape, motion, but there is no colour, scent, beauty in that world : there is no purpose, no emotion, no love. That is why it is so utterly dangerous to treat the world which the scientist has abstracted for study from what he perceives, as if it were the totality of things ; and that is the fallacy of the materialist.

Thus we may think that Galileo may be called, if any man may be so called, the originator of modern science, and as such it is impossible to overestimate his significance for human history.

## REVIEWS OF BOOKS

**Man and Energy.** By Prof. A. R. UBBELOHDE, F.R.S. (London : Hutchinson's Scientific Press). Pp. 209. Price 18s.

While the broadcast lectures on which this book is based may well have stimulated the interested layman, they make unimpressive reading.

At the start, Prof. Ubbelohde takes pains to distinguish between " animate " and " inanimate " energy. In conversation, the ellipsis would be accepted. In print, the suggestion that there are *kinds* of energy as well as forms of energy is confusing ; and what exactly does

it mean to call the horsepower a "neo-animate unit"? or, for that matter, a "measure of energy" (p. 60)?

Even in the chapters dealing with thermodynamics the outline is a little blurred. It is implied on p. 155 that entropy changes can only be written down for reversible processes. When $h$ is called "the quantum of *minimum* action" one suspects some confusion between Maupertuis and Planck. A report, quoted from the *Irish Times* of an Indian girl said to have fasted for a year is examined seriously. "In so far as such cases really do evade the laws of thermodynamics, this is made more likely to imply an evasion of the Second Law than any organic use of nuclear energy." This may be so, but is there any reason for suspecting that demoniac possession could operate quantitatively on such a scale—unless it is the kind of demon that makes people fast in barrels at Blackpool?

Other examples can be quoted. Thus, on p. 222: "light rays can blacken a photographic plate, by liberating some of the chlorine or bromine from the silver salts in the plate, leaving the black metallic silver to form a visible image." The vagueness might be pardoned, since most readers will be sufficiently acquainted with photography to know better; but not in this context, where the point is the conversion of energy. Surely this is almost entirely supplied as chemical energy during development?

Better physics but a cramped batting style appear in the author's observations on cricket. He speaks on p. 25 of the bat as a kind of lever, and on p. 174 of the ball leaving the bat with its kinetic energy reduced. The two statements are sadly consistent, but in a book which may well fall into the hands of schoolboys only one physical aspect is permissible—the ballistic pendulum pivoted freely at the left wrist, swinging in a vertical plane from a high back lift.

Nevertheless, the book has some good features, it gives some interesting statistics on the world's consumption of power, discusses the social implications of the growing trend towards complete mechanization, and warns the householder of the inevitable results of the reckless use of coal. The illustrations and diagrams are good, and there is precision plentifully sprinkled and to spare in such things as the dating of Clausius (—"A.D.") and Mr. Pecksniff (1842–43).

It must be admitted that if I had heard the broadcasts I should probably have enjoyed them, and remembered afterwards the story of the daughter of Cheops which was new to me, the rhyme about Humpty Dumpty which I had heard before, and the definition of $g$ as "a gravitational constant" which I hear all too often. Such

trivialities, indeed, are all that I have brought away from the book read in the cold deliberation of the study. True, it does give an interesting account of the history of man's struggle with his environment, but on the human side it bears no comparison with, say, Butterfield or Singer. Scientifically, it lacks both the conciseness that pins the reader's mind down to follow an argument in detail, and the clear-cut accuracy that would reward such attention. This is a harsh judgment, but to deserve the confidence of the layman a popular scientific work must achieve the highest excellence, far above the tolerances allowed by the specialist. One final query might be added: why, if surnames must be misspelt, is Sir J. J. Thomson the inevitable victim, and never William or Benjamin ?

G. R. NOAKES.

**What every engineer should know about rubber.** By W. J. S. NAUNTON. (London : British Rubber Development Board). Pp. 126. Price 3s. 6d.

The subject of rubber as an engineering material is one which has not received the attention which it deserves ; the appearance of a short book on the subject is therefore welcome. In this book the author gives an account of the many uses to which rubber may be put. These include electrical insulation, chemically resistant coatings, anti-vibration mountings and shock-absorbers, and a variety of engineering applications. A brief discussion of the basic manufacturing techniques and of the chemical and physical limitations of the material is also included.

The engineer will find much of interest in this book, but its educational value is limited by careless presentation, and by the lack of any clear statement or analysis of any particular problem. There is a complete absence of quantitative information on the actual mechanical properties of rubber, and curves are given either without numerical scales (e.g. Figs. 7, 11, 13, 19, 21) or with useless scales (e.g. deflection in inches of an unspecified dimension). Many statements will cause the physicist to shudder, e.g. " Modulus applied to metals means either the shear or elastic modulus and is a ratio of stress to strain : applied to rubber modulus means a stress to cause a somewhat arbitrary elongation and is used loosely as a synonym for stiffness."

The reader of this book will find no hint of the extensive recent developments in the field of rubber physics or of the theoretical solution of many problems of the engineering type by Rivlin and co-workers.

L. R. G. TRELOAR.

**Elements of Statistical Mechanics.** By D. TER HAAR. (New York : Rhinehart & Co. Ltd.) Pp. 468 + xix. Price $8.50.

There can be no doubt that ter Haar's book is an important contribution to the literature on statistical mechanics. It is intended primarily as a textbook for post-graduate students and as a research tool.

The book is divided into four parts. The first deals with the statistics of independent particles using the notions of Boltzmann's theorem on collisions, and the H-theorem to establish the Maxwell-Boltzmann distribution, and then the distributions associated with quantum statistics. The treatment of the various combinatorial problems which arise is particularly clear. The second part discusses petit and grand ensembles both in classical and quantum theory, the density matrix being applied in the latter case. Applications of statistical mechanics constitute the third part, and consist of treatments of equations of state for gases, condensation phenomena, electron theory of metals, semi-conductors, co-operative phenomena, statistical methods in nuclear physics, the equilibrium theory of the origin of the elements, and the statistical theory of rubber elasticity. The last part consists of a number of appendices in which more advanced topics are discussed. These include a good discussion of the H-theorem and the ergodic theorem, irreversible processes, the third law of thermodynamics, the Darwin-Fowler method, intermolecular forces, relativistic statistics and a mathematical appendix. Each chapter is supplemented by carefully prepared bibliographical notes.

An overall impression of the book is that no pains have been spared to make it logically sound and appealing to the imagination. It is a beautiful book, not only in the sense of avoiding ugliness by resolutely rejecting fallacious arguments, but in the positive sense of possessing a coherent and harmonious style of exposition. One has the sense of a great canvas being filled in as the story unfolds : Tolman's book also produces this impression, but few others do so. Dealing as it does both with fundamentals and applications, ter Haar's book is in a class by itself : the most informative, thoughtful and intelligent single work of its kind in existence.

It is properly indexed under authors and subjects, and well produced both in format and binding.

W. K. BURTON.

**Sound.** By R. C. Brown. (London : Longmans Green and Co. Ltd.) Pp. 690. Price 10s. 6d.

This forms the third volume in the Text-book of Physics of Dr. R. C. Brown. There have been quite a number of texts of

Intermediate standard in the past few years, amongst which this takes an honourable place. In common with the other sections of the text-book, each chapter is followed by a set of questions, mostly taken from the Inter.Science papers of universities. The text is mainly descriptive and is illustrated by numerical examples. Modern developments in ultrasonics and acoustical measurements are given due attention.

E. G. RICHARDSON.

## NOTICES TO MEMBERS

### Proceedings of Extraordinary General Meeting

An Extraordinary General Meeting of the Institute was held on December 15, 1954, at the Institute's House. Dr. J. S. Forrest was in the Chair. A quorum being present the Secretary read the notice convening the meeting. The following resolution was proposed by Mr. B. S. Cooper (Fellow) and seconded by Dr. R. Taylor (Fellow) :—

> That in By-law 32 the words "ten shillings and sixpence" be substituted for the words "one guinea" and the words "five shillings" be substituted for the words "seven shillings and sixpence."

After a brief discussion of the resolution, a poll was demanded by the Chairman in accordance with Article 77. Dr. D. H. Follett (Fellow) and Professor A. M. Taylor (Fellow) were appointed scrutineers for the ballot. 417 members had appointed Dr. H. R. Lang (Fellow) to act as their proxy. The resulting vote on the resolution was 415 for and 14 against. The resolution was declared carried.

By-law 32 relates to the annual subscription payable by Students. The new annual fee for Students resident in the United Kingdom is 10s. 6d. and that for Students resident abroad is 5s. Students in National Service are required to pay only one fee of 10s. 6d. to cover the two years of service.

### Binding of Journals

Orders can now be accepted for binding the 1954 volumes of the *Journals* in the standard case for 18s. 6d. post free. Separate cases can be supplied for 12s. 0d. each.

Orders, and parts, accompanied by a remittance, should be sent to the Institute and not to the binders as heretofore.

## PHYSICAL SOCIETY MEETINGS

Members of the Institute are invited to attend any of the following meetings of the Physical Society's groups :—

| *Date* | *Title* | *Lecturer* | *Place* |
|---|---|---|---|
| January 13, 4.30 p.m. Low Temperature Group | The Petrochemicals low temperature gas separation column | Mr. W. A. Levick | London : Science Museum |
| January 20, Acoustics Group | Aspects of wave propagation in fluids | Dr. R. O. Davies | London : Imperial College |
| January 27, Optical Group | Some applications of multiple Fabry-Perot interferometers | Dr. G. W. Series | London : Imperial College |
| | The Hilger-Watts surface micro-interferometer | Mr. J. W. Perry | |
| | A new aligning device | Mr. K. R. Coleman | |
| February 3, 5.30 p.m. Acoustics Group | | Prof. O. K. Mawardi | London : Imperial College |
| February 8, 4.30 p.m. Low Temperature Group | Some physical properties of solid argon | Mr. R. F. Followell | London : Science Museum |
| February 18, 5.00 p.m. Acoustics Group | The Festival Organ | Dr. R. Downs<br>Mr. C. T. L. Harrison<br>Mr. H. Creighton<br>Dr. E. G. Richardson | London : Festival Hall |

## NEWS OF MEMBERS

### Fellows

C. R. BURCH has been awarded the Rumford Medal of the Royal Society "for his distinguished contributions to the technique for the production of high vacua and to the development of the reflecting microscope."

SIR JOHN COCKCROFT has been awarded a Royal Medal on the recommendation of the Council of the Royal Society "for his distinguished work on nuclear and atomic physics."

F. W. CUCKOW has taken up an appointment with the National Coal Board, Isleworth.

H. T. RAMSAY is now Deputy Director of the Safety in Mines Research Establishment.

F. I. G. RAWLINS has been appointed Secretary of the Central Council for the Care of Churches. Initially the appointment will be part-time. The Council advises on the preservation and care of the art treasures of the cathedrals and parish churches of the country.

N. TUNSTALL has become Head of the Science Department, Girls' Grammar School, Grimsby.

C. N. WATSON-MUNRO is Chief of Research to the Australian Atomic Energy Commission, Sydney, Australia.

**Associates**

A. J. BIRD has recently taken up a post with Shell Petroleum Co. Ltd., as a research physicist.

J. R. BARKER is now a Lecturer in electrical engineering at Imperial College, London.

D. C. DAVIES has been promoted to Squadron Leader in the Royal Air Force Education Branch.

E. GILLAM has taken up an appointment in the Division of Tribophysics of the Commonwealth Scientific and Industrial Research Organization, University of Melbourne.

M. P. GUPTA is with the National Research Council of Canada with a postdoctorate fellowship.

S. C. HAYDON has recently taken up a post in the Department of Physics, University of New England, New South Wales, Australia.

H. A. HUGHES has been appointed Principal Physicist at the Western General Hospital, Edinburgh.

A. A. JOHNSON is now at the Admiralty Research Laboratory, Teddington.

R. W. MACKAY is senior research assistant, John Brown Land Boilers Ltd., Clydebank.

V. P. N. NAMBYAR has been promoted to be Professor and Head of the Department of Physics, Pachaiyappa College, Madras.

W. P. OSMOND has become senior physicist at the Mullard Research Laboratories, Cross Oak Lane, Salfords.

A. REES is headmaster of Brecon Boys' County Grammar School.

C. V. TAYLOR is in the Electrical Department of C.A.V., Acton, as a development engineer.

W. A. RUNCIMAN has been appointed to a senior research fellowship at the Atomic Energy Research Establishment, Harwell.

M. G. SMITH is extension lecturer in science in the Extra-Mural Department of King's College (University of Durham), Newcastle-upon-Tyne.

### Graduates

D. C. BISSET is now with Bexford Ltd., Brantham.

F. P. CHAPPEL has taken up an appointment with British Nylon Spinners, Ltd., as a technical assistant.

G. J. MARRISON is employed as a physicist by Salford Electrical Instruments Co. Ltd., Heywood.

T. L. WATKINS is in the central research department of Morgan Crucible Co. Ltd., Battersea, as a physicist.

## THE REGISTER

ELECTIONS TO MEMBERSHIP

An asterisk (*) indicates transfer from another grade

*Fellows*

*Brooks, Jack Mervyn, B.Sc., Headmaster, Queen Elizabeth Grammar School, Hexham.

*Harries, Glanville, Ph.D., Principal Scientific Officer, Royal Naval Scientific Service.

*Maddock, Ieuan, B.Sc., Superintendent of Electronics, Trials and Electronics Division, Atomic Weapons Research Establishment, Berkshire.

*Newbery, George Richard, B.Sc., Physicist, Radiotherapeutic Research Unit, Medical Research Council, Hammersmith Hospital.

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Howarth, Philip, B.Sc., Scientific Staff, Research Laboratories, The General Electric Co. Ltd., Wembley.

*Graduates*

*Allen, Kathleen Mary, B.Sc., Junior Electronics Engineer, Electric and Musical Industries Engineering Development Limited.

Ashworth, Derek Ralph, M.Sc., Research Work Grade I, British Scientific Instrument Research Association, Kent.

Ball, Derek, B.Sc., Assistant Technical Officer, Imperial Chemical Industries Ltd., Welwyn, Herts.

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Barnard, Anthony Charles L., B.Sc., Research Student, University of Birmingham.

Beardshall, Dennis, B.Sc., Assistant Experimental Officer, Ministry of Fuel and Power, Safety in Mines Research Establishment.

*Boylett, Frank D. A., B.Sc., Research Student, University College, London.

Bradley, Edward Frank, B.Sc., Assistant Experimental Officer, Ministry of Supply.

Bullen, Colin Christopher, B.Sc., Assistant Physicist, Chance Brothers Ltd., Smethwick.

Davies, Robert H. A., B.Sc., Technical Officer, Ferodo Limited, Chapel-en-le-Frith.

Dodd, Ivor David, B.Sc., Senior Development Engineer, Simonds Aerocessaries Ltd., Treforest, Glam.

*Dunlop, Brian Richard, B.Sc., Physicist, Grade I, Commonwealth X-ray and Radium Laboratory, Victoria, Australia.

Durrant, John Kenneth Bloomfield, B.Sc., Assistant Lecturer, Guildford Technical College.

Haigh, Geoffrey, B.Sc., Research Student, Imperial College of Science and Technology, London.

*Haywood, Brian Charles, B.Sc., Research Student, University of Birmingham.

Higson, Gordon Robert, B.Sc., Technical Assistant, Structural Testing Department, Fairey Aviation Co. Ltd., Hayes.

Jones, Clifford Seville, B.Sc., Geophysicist, Anglo-Iranian Oil Company.

*Jones, David R. L., B.Sc., Research Student, University College of Swansea.

*Kalman, Peter, B.Sc., In Charge of Development Section, Anchor Glass Co. Ltd., London.

Kuffel, Edmund, M.Sc., Research Physicist, British Rayon Research Association, Manchester.

Laite, Peter J., B.Sc., Scientific Officer, Ministry of Supply, R.R.E. (South), Malvern.

*Norcross, Eric, B.Sc., Technical Assistant, Mullards Blackburn Works Limited, Blackburn, Lancs.

*Payne, William R., B.Sc., Scientific Staff, Research Laboratories, The General Electric Co. Ltd., Stanmore, Middlesex.

Pearson, Keith William John, B.Sc., Research Assistant, The Telegraph Construction and Maintenance Company Ltd., London.

Robertson, Gavin William Edward, B.Sc., Chemist, North Thames Gas Board.

Seal, Michael, B.A., Research Student, P.C.S. Laboratory, Department of Physical Chemistry, University of Cambridge.

*Sewell, Peter Broun, B.Sc., Research Student, Department of Physics, University of Western Australia.

Stringfellow, Michael Walter, B.A., Technical Officer, Dyestuffs Division, Imperial Chemical Industries Ltd., Manchester.

*Trotman, Robert Edward, B.Sc., Physicist, Westinghouse Brake and Signal Co. Ltd., London.

Whelan, Michael John, B.A., Research Student, University of Cambridge.

White, Noel Elvie, B.Sc., Graduate Research Student, University of Western Australia.

Wilcox, Ronald J., B.Sc.Tech., Valve Development Engineer, Ferranti Ltd., Manchester.

Wright, Alan Mark Heyden, B.Sc., Assistant Experimental Officer, Radio Research Station, Slough, Bucks.

**Central Research Establishment, National Coal Board** (at Isleworth, Middlesex), which is concerned with mining problems, invite applications for a superannuable appointment of a **physicist** to lead a group carrying out research on underground transport of coal. The work will be concerned initially with belt conveyors and includes measurements of stress set up in the belt plies under working loads and the study of relevant physical properties of belt materials which determine their optimum performance and long life.

Candidates should have a good honours degree in physics or equivalent professional qualifications, proved research ability and preferably experience in strain measurements and/or mechanical properties of materials.

Appointment will be as a scientist I (scale £1,150 × £40 to £1,350 followed by a range to £1,550 male), London Location Allowance of £82 at the minimum rising to £100 at the maximum is payable in addition.

Write, giving full particulars (in chronological order) of age, education qualifications and experience (with dates) to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/899. Original testimonials should not be forwarded. Closing date January 15, 1955.

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**Ministry of Supply** require for radio division, **Royal Aircraft Establishment, Farnborough, Hants.** 1. **Scientific officer**—physicist with good mathematical background to study application of titanate ceramics and similar materials to radio frequency problems. An interest in physics of the solid state is required and electronics experience desirable. 2. **Senior scientific officer or scientific officer**—electrical engineer or physicist for research on special radio transmitting systems, in particular concerned with microwave region and with studies of modulation characteristics and frequency spectra. Qualifications :—1st or 2nd class honours degree or equivalent. For senior grade a minimum of three years post-graduate research experience is essential. Salary within ranges—Senior Scientific Officer (minimum age 26) : £935–£1090 p.a. Scientific Officer : £445–£815 p.a. Women somewhat less. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.353/54A. Closing date January 24, 1955.

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Large British Oil Company has vacancies for **geophysicists** on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £820 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to Box 1223, c/o 191 Gresham House, E.C.2.

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**College of Technology, Birmingham. Department of Physics and Mathematics.** There is a vacancy for a **research assistant** to take part in the development of an electronic aid for the blind. Experience in the design of electronic circuits is essential and practical acquaintance with television or sound-film recording techniques would be an advantage. Candidates must also have a good honours degree in physics preferably from a University which will award higher degrees externally. Applicants will be expected to undertake a certain amount of teaching.

Salary will be in accordance with the Burnham (Further Education) Scale for Grade "A" Assistants. Basic salary (Men) £510 with increments for approved training and industrial or teaching experience.

Further particulars and form of application may be obtained from the Registrar, College of Technology, Suffolk Street, Birmingham, 1, on receipt of a stamped addressed foolscap envelope. Completed forms should be returned not later than two weeks after the appearance of this advertisement.

K. R. Pilling,
Clerk to the Governing Body.

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War Department requires **demonstrator in physics** at **Royal Military College of Science, Shrivenham, Berks.** Qualifications : honours degree in physics, salary £465 to £590 according to age and experience. Minimum age 21. Superannuation F.S.S.U. Accommodation available for both married and single staff. Good facilities for research ; work and living conditions similar to those of provincial residential university. Successful candidate to take up duty as soon as possible. Appointment normally for three years. Service counts as approved experience for starting salary in Scientific Civil Service, etc. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A340/54A. Closing date January 24, 1955.

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**Aerodynamicists, mechanical and electrical engineers, physicists** and **physical chemists** required by **Ministry of Supply, National Gas Turbine Establishment,** near Farnborough, Hants. First or second class honours degree or equivalent in appropriate subject. Research and development experience related to power plant preferably gas turbines would be an advantage. Houses can be available in reasonable time for candidates with family responsibilities not locally resident. Salary within Principal Scientific Officer range (minimum age 31) £1,090–£1,472. Women somewhat less. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting C780/54A. Closing date January 24, 1955.

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**Electric lamp development engineer, Crompton Parkinson Limited** have a vacancy in their lamp development and research laboratories at Guiseley for experienced lamp or radio valve technician, capable of carrying out specific investigations and development work on electric discharge lamps, etc. The position vacant offers good salary rates and good prospects of promotion. Preference given to graduate physicist or electrical engineer. Superannuation scheme. Write in confidence with full details to Reference LLD, Crompton Parkinson Limited, Guiseley, Nr. Leeds.

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(*Continued on page vi*)

**Engineers and physicist.—Ferranti Limited** in their new laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computers to control machines and industrial processes, and covers a wide and expanding field of application, offering long-term interest to those engaged in it.

Development activity for these projects is taking place in the fields of electronic circuitry (including pulse technique), digital computers, magnetic recording and servo-mechanisms. Engineers and physicists having experience as well as interest in one or more of these subjects are invited to apply.

The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff Pension Scheme. Application form will be sent on request (quoting Ref. EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5.

**The United Kingdom Atomic Energy Authority**

invites

**Mathematicians and Theoretical Physicists** to join the Atomic Weapons Research Establishment to investigate a range of problems in classical and nuclear physics.

Those interested should apply in the first instance to Mr. W. R. J. Cook, Deputy Director, A.W.R.E., Aldermaston, Berkshire, giving details of their academic training and research experience. The posts are pensionable. Salary will be in the range of £1,700 – £2,250 per annum. Houses, on a rental basis, will be available within a reasonable period for married officers who live outside the radius of the Establishment's transport facilities.

**Central Research Establishment, National Coal Board** (at Isleworth, Middlesex) which is concerned with mining problems, invite applications for a superannuable appointment of a **physicist** to carry out research on strata studies. The work will be concerned initially with measurement of rock pressures.

Candidates should have a good honours degree in Physics or equivalent professional qualifications and preferably some experience in research and field experiments.

Appointment will be according to qualifications and experience as either Scientist II (scale £800 × £35 to £1,150 male, and £700 × £30 to £1,000 female) or Scientist III (scale £500 × £25 to £950 male and £475 × £20 to £835 female), London Location Allowance of £34 at the minimum rising to £82 at the maximum of the scales is payable in addition.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/900. Original testimonials should not be forwarded. Closing date January 22, 1955.

**University of Hull**

Applications are invited for the **Chair of Physics.** Minimum salary £2,000 per annum with F.S.S.U. and children's allowances. Further particulars may be obtained from the Registrar to whom applications (12 copies), together with the names of three referees, should be submitted not later than February 28, 1955.

**Imperial Chemical Industries Limited, Billingham Division,** has vacancies for **physicist** and **mechanical engineering male assistant technical officer** posts in their engineering research laboratories. Candidates should not be more than 27 years of age and should have an Inter-B.Sc., a pass degree or a Higher National Certificate qualification. Salary will depend on qualifications and experience but as an indication, candidates could expect to rise to a salary of £730, £850 or an even higher figure. Write, giving brief details of career to the Staff Manager, Imperial Chemical Industries Limited, Billingham Division, Co. Durham, quoting reference W.1.

**International Union of Crystallography**

**Commission on Structure Reports**

Applications are invited for the post of **Assistant Editor** (man or woman) of Structure Reports. Qualifications : knowledge of chemistry and particularly chemical nomenclature, reading knowledge of principal European languages, interest in printing. University degree and knowledge of physics or mineralogy desirable. Salary in the range £500 by £50 to £650. The appointment will be for one year, and may be renewed for further periods of one year. Place of work Cardiff. Duties to commence as soon as possible, and not later than October 1, 1955

Applications (three copies) should be addressed to Professor A. J. C. Wilson, Department of Physics, University College, Cardiff, Great Britain, from whom further information may be obtained.

**Mullard Blackburn Works Ltd.** have vacancies for the following :—

**Senior Physical Chemist** to take charge of the development laboratory working on ceramic magnetic materials. Some experience of solid state physics and chemistry is essential. The work is closely connected with a rapidly expanding industry, and offers considerable scope for advancement. Salary depending upon age, qualifications and experience will be within the scale £800 – £1,100. Ref. M/24.

**Senior Metallurgist** required for Works Laboratory. Candidates should have a good degree in Metallurgy and considerable experience in the investigation of factory problems. The work will be concerned with the metallurgical problems involved in the manufacture of lamps and radio valves including the production of tungsten and molybdenum. Some experience in powder metallurgy would be an advantage. Age 35–45 yrs. Salary according to qualifications and experience within the scale £925 – £1,200. Ref. M/26.

**Metallurgist** to work on the development of magnetic materials including permanent magnet alloys. Applicants must possess a degree in Metallurgy. Some specialized knowledge of physical metallurgy would be an advantage. Salary according to age and experience within the scale £600 – £800. Ref. M/25.

Apply in writing giving full details to the Works Personnel Officer, Mullard Blackburn Works Ltd., Philips Road, Blackburn, Lancs., quoting appropriate reference.

**Department of Scientific and Industrial Research : Principal Scientific Officer.** The Civil Service Commissioners invite applications for a pensionable post at the Mechanical Engineering Research Laboratory, East Kilbride, near Glasgow.

The officer appointed will be required to lead a team preparing tables of thermodynamic properties. Experimental data relating to functions of two variables are to be correlated.

Age at least 32 on December 31, 1954. Candidates must have a first or second class honours degree in mathematics, physics of engineering, or equivalent qualifications and some post-graduate research experience. Exceptionally a candidate without the prescribed qualifications may be admitted. A high degree of mathematical ability and a specialist knowledge of numerical mathematics expected. Experience in using calculating equipment and in sifting crude data an advantage.

Inclusive annual remuneration (for 45½-hour week) £1,122–£1,516 (men), £1,007–£1,354 (women). Exceptionally a starting salary above the minimum may be granted according to qualifications and experience.

East Kilbride is a new town with good housing prospects.

Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S4402/55. Applications must be returned by January 18, 1955.

**Department of Scientific and Industrial Research : Principal or senior scientific officer.** The Civil Service Commissioners invite applications for a pensionable post in the Radio Research Station, Ditton Park, Slough, Bucks.

Duties :—To lead a small but expanding group investigating the fundamental electrical properties at high frequencies of materials of interest in radio applications and the relation of these properties to their physical and chemical structure. Items at present under investigation include semi-conductors, ferromagnetic and ferroelectric materials and special dielectrics.

Candidates must have been born on or before December 31, 1928. They must have a 1st or 2nd class honours degree in physics or physical chemistry or equivalent qualification. Exceptionally a candidate without these qualifications may be considered. At least 3 years university or industrial research essential.

Inclusive annual remuneration (for 45½-hour week) £1,122–£1,516 (£1,007–£1,354 women) or £963–£1,122 (£829–£1,007 women) according to grading. A starting salary above the minimum may be granted.

Further particulars and application form from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S4399/55. Completed applications to be returned by January 20, 1955.

## ASSISTANTS

**Assistant** with interest in properties of matter, required for research on behaviour of packaging materials under shock. A familiarity with electronic circuits useful. G.C.E. Advanced level in Physics and Mathematics preferably with laboratory experience £275 – £475. Male applicants should have completed or be exempt from National Service. Application forms from Secretary, Printing, Packaging and Allied Trades Research Association, Randalls Road, Leatherhead, Surrey. Ref. CM/2.

**Technical Assistant** required for work on the development of testing of semi-conductor devices. The work will be of a varied nature and will require electrical knowledge and some mechanical aptitude. Candidates should possess a Higher National Certificate or a National Certificate in Applied Physics and should have completed or be exempt from National Service. Apply in writing, giving particulars of qualifications, experience to the **Staff Manager (Ref. RLP/412), Research Laboratories of The General Electric Co. Ltd., East Lane, North Wembley, Middx.**

**City of Portsmouth College of Technology**

Principal : W. Taylor, D.Sc., F.R.I.C.

Applications are invited for the post of **instrument maker** in the physics department of the City of Portsmouth College of Technology. Salary will be paid within the scale £395 to £460 and thence by three annual increments of £30 £15, £15 to £520. Applicants should have had a good general education and some practical experience of instrument repair work. Applications, giving full details, together with the names of two referees, should be forwarded to the Registrar of the College not later than January 14, 1955.

E. G. Barnard,
Chief Education Officer.

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